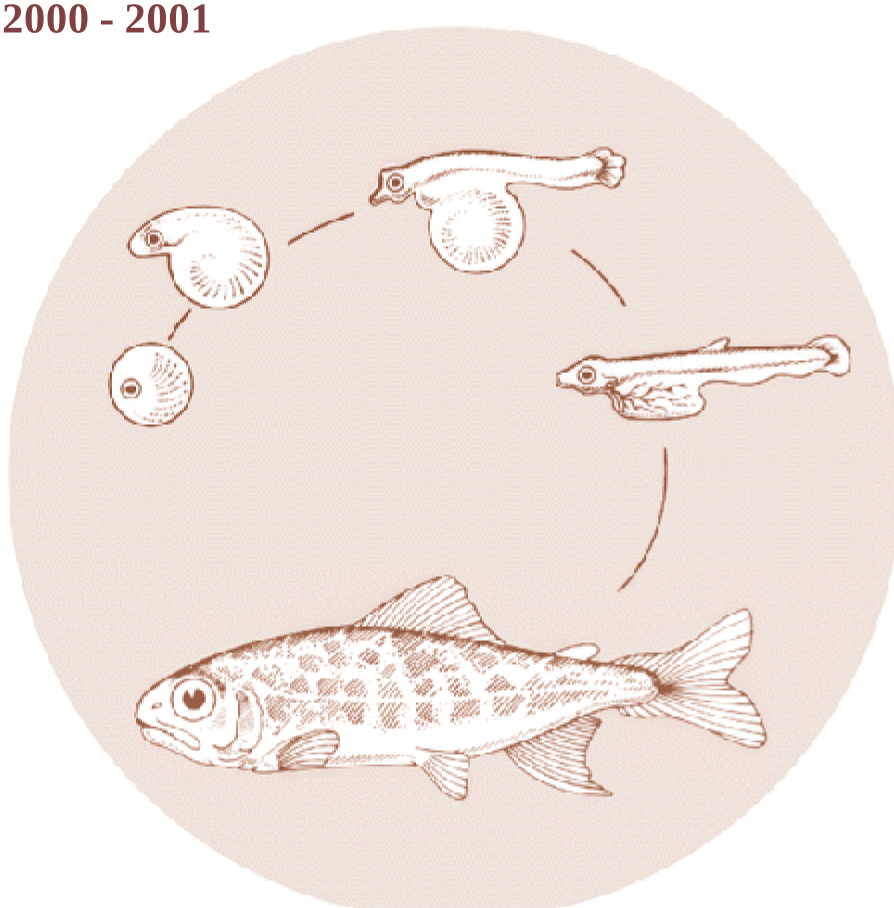
Redfish Lake Sockeye Salmon Captive Broodstock Rearing and Research

Annual Report
2000 - 2001



DOE/BP-00004664-1

April 2002

This Document should be cited as follows:

Frost, Deborah, W. McAuley, Desmond Maynard, Thomas Flagg, ''Redfish Lake Sockeye Salmon Captive Broodstock Rearing and Research'', Project No. 1992-04000, 27 electronic pages, (BPA Report DOE/BP-00004664-1)

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P.O. Box 3621
Portland, Oregon 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

REDFISH LAKE SOCKEYE SALMON CAPTIVE BROODSTOCK REARING AND RESEARCH, 2001

Annual Report

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Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621
Department of Energy

Contract No. 00004464
Project No. 1992-040-00

April 2002

ABSTRACT

The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center, in cooperation with the Idaho Department of Fish and Game and the Bonneville Power Administration, has established captive broodstock and captive rearing programs to aid recovery of Snake River sockeye salmon (*Oncorhynchus nerka*) listed as endangered under the U.S. Endangered Species Act (ESA). Captive broodstock and captive rearing programs are a form of artificial propagation that are emerging as an important component of restoration efforts for ESA-listed salmon populations that are at critically low numbers. Captive broodstocks, reared in captivity for the entire life cycle, couple the salmon's high fecundity with potentially high survival in protective culture to produce large numbers of juveniles in a single generation for supplementation of natural populations.

The captive broodstocks discussed in this report were intended to protect the last known remnants of sockeye salmon that return to Redfish Lake in the Sawtooth Basin of Idaho at the headwaters of the Salmon River. This report addresses NMFS research from 1 September 2000 to 31 August 2001 on the Redfish Lake sockeye salmon captive broodstock and captive rearing program. NMFS currently has broodstock in culture from year classes 1997, 1998, 1999, and 2000 in both the captive broodstock and captive rearing programs. Offspring from these programs are being returned to Idaho to aid recovery efforts for the species.

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INTRODUCTION

In 1992, the National Marine Fisheries Service (NMFS), Northwest Fisheries Science Center (NWFSC), in cooperation with the Bonneville Power Administration (BPA) and the Idaho Department of Fish and Game (IDFG) began a captive broodstock program for Redfish Lake sockeye salmon. These fish were listed as endangered under the U.S. Endangered Species Act (ESA) in 1991. From 1991 to 1998, a total of 16 wild adult anadromous sockeye salmon returned to Redfish Lake in the Stanley Basin of Idaho (Figure 1). These wild returning fish were incorporated into the NMFS captive broodstock program, which has produced over 800,000 eyed eggs, about 614,000 of which were sent to IDFG to supplement egg and fry outplants into Stanley Basin lakes and about 162,000 of which were reared and transferred to IDFG as smolts for release, and 181 prespawning adults for use in recovery efforts (Frost et al. 2001). Releases from the NMFS and IDFG captive broodstock programs generated seven returning adults in 1999, 257 returning adults in 2000 (Kline and Willard, 2001) and 26 returning adults in 2001.

The captive broodstock program initially served as a gene conservation program to prevent the loss of this evolutionary significant unit. However, the high fecundity of Pacific salmon, coupled with increased survival in protective culture, allowed the program to produce large numbers of spawnable fish in a single generation. These fish provided a means of rapidly increasing the abundance of offspring available for restoration releases in the Stanley Basin lakes (Flagg et al. 1995, Schiewe et al. 1997). At every opportunity, the captive broodstock program incorporates adults returning from the sea to help ensure the continued adaptation of these fish to their natural environment.

The NMFS captive broodstocks complement those reared by IDFG to reduce the risk of catastrophic loss from mechanical failure, human error, or disease. Prespawning

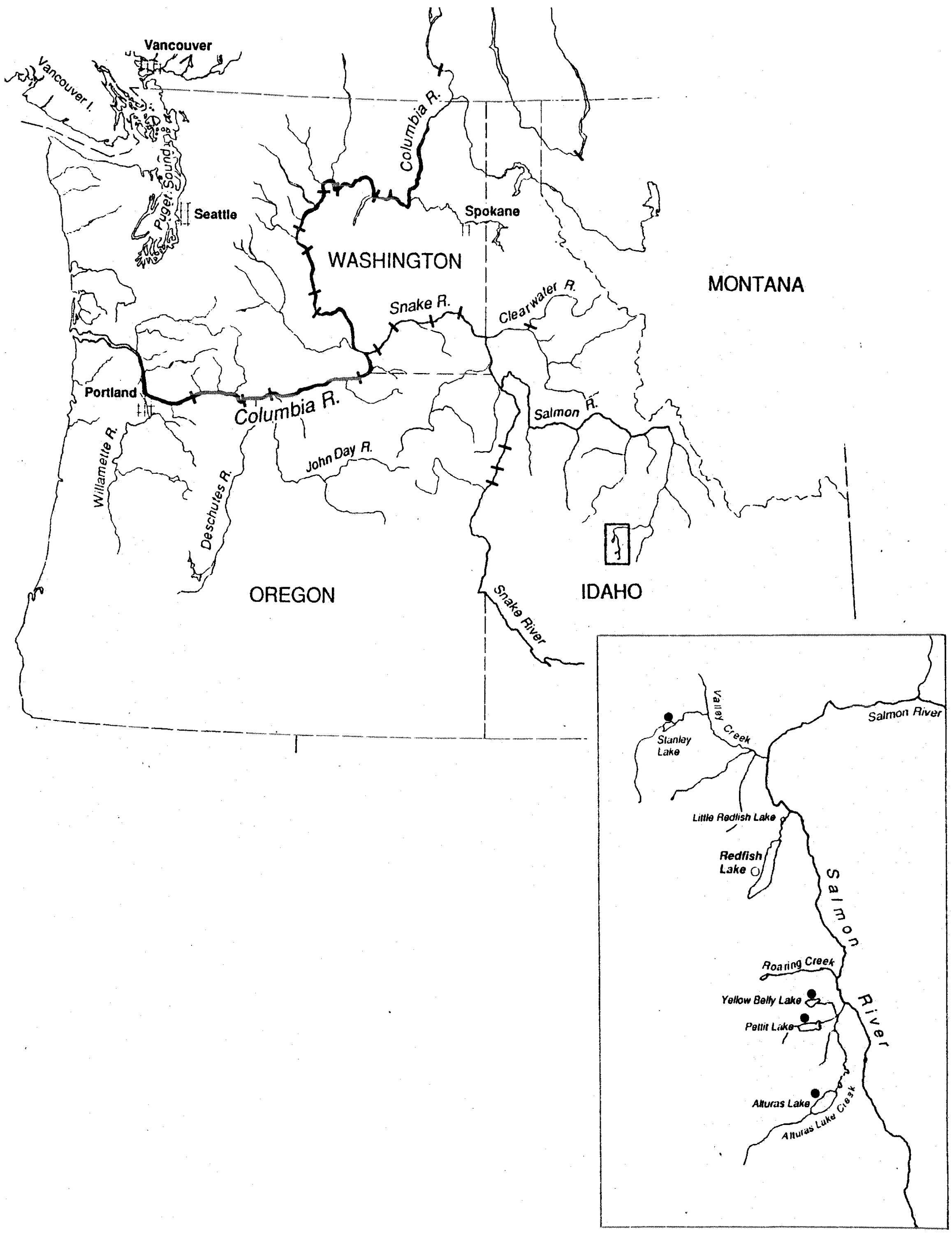

Figure 1. Map showing location of Redfish Lake. Sockeye salmon returning to Redfish Lake travel a greater distance from the sea (almost 1,450 km) and spawn at a higher elevation (almost 2,000 m) than any other sockeye salmon population.

adults, eyed eggs and juveniles from NMFS captive broodstocks are provided to IDFG to assist in the recovery of self-sustaining runs of sockeye salmon in the Stanley Basin.

Recovery activities for NMFS and IDFG Redfish Lake programs are coordinated by the Stanley Basin Sockeye Salmon Technical Oversight Committee (SBSTOC). Membership on the SBSTOC includes IDFG, NMFS, BPA, the Shoshone-Bannock Tribe, the University of Idaho, and private groups concerned with sockeye salmon restoration in Idaho. NWFSC staff participate in bimonthly SBSTOC meetings.

The following report summarizes the operation of the NMFS Redfish Lake sockeye salmon captive broodstock program from 1 September 2000 to 31 August 2001. The report describes the facilities, fish culture practices, and the status of the various rearing groups in the captive broodstock program.

FACILITIES

The NMFS Redfish Lake sockeye salmon captive broodstock project is divided between two facilities. The seawater facility is located at the NMFS Manchester Research Station (MRS) located on Clam Bay, a small bay adjoining the central basin of Puget Sound in Washington State. The MRS consists of several buildings with offices, laboratories, and a land-based seawater captive broodstock rearing complex. The freshwater phase of sockeye salmon rearing was initially carried out at the University of Washington's Big Beef Creek (BBC) Research Station near Seabeck, Washington. When a new freshwater rearing facility at Burley Creek Hatchery (BCH) near Port Orchard, Washington was completed in July 2001, the freshwater component of the NMFS captive broodstock sockeye salmon was transferred from BBC to BCH.

The seawater phase of the sockeye salmon life cycle is accomplished at the MRS. The annual seawater temperature at the site normally ranges between 7 and 14°C, and salinity ranges between 26 and 29 ppt. A 250-m pier, made available to the station by the Environmental Protection Agency Region X Laboratory, provides access to 50-hp centrifugal pumps that supply about 5,000 L/min (1,250 gpm) of seawater through a 700-m long pipeline to the station's land-based facilities. Back-up 50-hp pumps are available in case of primary pump failure. An alarm system monitors the pumps and electrical supply and is tied to an automatic dialer system linked to pagers and home telephones.

Redundant emergency generators are automatically serially activated in the event of a power failure.

At MRS, the captive broodstock rearing is conducted in two buildings. A 400-m^2 area in one building contains six 4.1-m diameter circular tan fiberglass tanks and four 3.7-m diameter circular gray fiberglass tanks. A 1,280-m^2 building houses 20 6.1-m diameter circular gray fiberglass tanks. Portions of both buildings are used for the project. The seawater supplied to these tanks is processed to prevent naturally occurring pathogens from entering the rearing tanks. The processing consists of filtering through primary sand filters that eliminate all organic and inorganic material larger than 20 microns in diameter and secondary cartridge filters that screen out all material larger than 5 microns in diameter. The water then passes through an ultraviolet (UV) system to inactivate remaining organic material. Sensors monitor water flow and pressure through the seawater filtration system.

Before entering fish rearing tanks, the processed seawater is passed through degassing columns to remove excess nitrogen and to boost dissolved oxygen levels. In addition, the tanks are directly supplied with oxygen to maintain life support in the event of an interruption in water flow. Rearing temperatures are maintained at or below 13^o C with combinations of ambient and chilled water. The station complies with Washington Department Fish and Wildlife (WDFW) quarantine certification standards by depurating all effluent from the captive broodstock rearing areas with ozone.

The captive broodstock facility at BBC housed six 4.1-m diameter circular tan fiberglass tanks and nineteen 1.8-m diameter circular blue plastic tanks in an enclosed building. In addition, six 4.1-m diameter circular tan fiberglass tanks and six 2.1-m diameter circular blue plastic tanks resided in an outdoor fenced area. A separate egg incubation room was equipped with down-well incubators for isolated egg incubation (Novotny et al. 1985). The facility was supplied with 2,000 L/min of 10^{o}C pathogen-free artesian well water. The facility's effluent was depurated through a settling basin and UV system to meet WDFW requirements. Water flow, fire, and intruder alarms were monitored through a security system. Interruptions in water flow activated an automatic emergency oxygen supply. In the event of a power failure an emergency generator was automatically activated to maintain electricity to the alarms and the effluent depuration system.

The new BCH facility contains eight 3.7-m diameter circular gray fiberglass tanks, three 3.6-m diameter circular green fiberglass tanks, and thirteen 1.5-m diameter circular blue plastic tanks. A separate egg incubation area accommodates down-well incubators for isolated egg incubation. The BCH facility is supplied by two pumped wells providing a total of 1,900 L/min of 10°C water. The water from each well passes through a degassing tower to remove excess nitrogen and to increase dissolved oxygen levels. Supplemental oxygen lines are supplied to each rearing container to maintain fish during interruptions in water flow. At the present time, the oxygen is controlled manually. In the event of a power failure, an emergency generator is automatically activated to power the well pumps and the UV depuration system. Fire and intruder alarms are monitored through a security system. Water and power alarms are linked to NMFS personnel pagers and telephones.

In cooperation with Oregon Department of Fish and Wildlife (ODFW), Redfish Lake sockeye salmon eggs are transported to and reared to smolt stage at Bonneville Fish Hatchery (BFH) near Cascade Locks, Oregon for the smolt release program. Facilities at BFH consist of 10°C well-water supplied vertical incubation trays, Canadian troughs (0.8-m by 0.5-m by 4.5-m), and 2.7-m diameter circular tanks in an enclosed building. In addition, fish are reared in outdoor raceways (6.1 m by 0.8 m by 24 m) supplied with either well water or 4 - 13°C Tanner Creek water. ODFW provides personnel for daily facility activities.

REINTRODUCTION STRATEGIES

The NMFS captive broodstock program has successfully generated sockeye salmon for release into the Stanley Basin lakes (e.g., Redfish, Alturas, and Pettit) at several different life history stages to help restore ESA-listed endangered Snake River sockeye salmon.

1) Egg box releases—Eyed eggs from captive-broodstock fish that are spawned at the NMFS freshwater facility are returned to Idaho for stocking egg boxes for in-lake hatching.

2) Presmolt releases—Eyed eggs from captive-broodstock fish that are spawned at the NMFS freshwater facility are returned to Idaho for rearing and release during the presmolt stage.
3) Smolt release-- Juveniles from captive-broodstock program eggs sent to BFH are reared to smoltification and transported to Idaho for release.
4) Adult release—Prespawning (maturing) adults reared in captivity are returned to Idaho for release into Stanley Basin lakes for volitional spawning.

NMFS obtained appropriate permits for interstate transport of all fish and progeny.

CAPTIVE BROODSTOCK FISH CULTURE PRACTICES

Each fall in 1997,1998, 1999, and 2000 NMFS received eggs shipped from IDFG spawning of Redfish Lake sockeye salmon for the broodstocks discussed in the current reporting period. NMFS also retained a safety net of eggs from its spawnings in 1998 and 2000 to be used in either the captive broodstock or the adult release programs. In winter 2000, NMFS received a transfer of 1999-brood fry for the adult release program.

The captive broodstock and adult release program fish were reared using standard fish culture practices and approved therapeutics (for a general overview of methods see Leitritz and Lewis 1976, Piper et al. 1982, FRED 1983, McDaniel et al. 1994, Schreck et al. 1995, Pennell and Barton 1996). Fish culture practices conformed to the husbandry requirements detailed in ESA Section 10 Propagation Permit 1148 for NMFS's rearing of Idaho stocks of ESA-listed Snake River sockeye salmon. Generally, juvenile-to-adult rearing density in the tanks was maintained at less than 8 kg/m^3 (0.5 lb/ft^3) during most of the culture period; however, fish density ranged to 15 kg/m^3 (1.0 lb/ft^3) at maturity. Loading densities in freshwater ranged from 0.24 kg/Lpm (2.0 lb/gpm) to 0.84 kg/Lpm (7 lb/gpm). Seawater loading densities ranged up to 1.08 kg/Lpm (9 lb/gpm).

Individual genetic lots of eggs were placed in separate isolation containers and incubated to swim-up stage. The containers were periodically checked for dead eggs and/or alevins. At swim-up stage, the alevins were moved in their containers from the incubation room to grow-out tanks (1.8-m diameter). The containers were placed into floating rings that held the container suspended in the tank water. The fry remained in the containers until they reached approximately 0.7 g, at which time they were dispensed into the entire tank. The fish were grown in these tanks until they were large enough to be tagged (usually > 120 mm in length) and combined into larger rearing pools (4.1-m diameter at BBC, 3.7-m diameter at BCH).

All large tanks (3.7 m-diameter and larger) used for sockeye salmon captive broodstock rearing were completely covered with a taut 2.5 x 2.5 cm or smaller mesh nylon netting to prevent fish from jumping out. In addition to the mesh, half of each tank was covered with black fabric to provide a covered refuge area fish could move under when disturbed.

A mild current (< 35 cm/sec) was generated in the rearing tanks by their circular shape, center drain, and a subsurface water jet inlet. This current provided a self-cleaning action in the tank and a very slight exercise potential. At least once a week, bottom material that was not swept out of the tank by the current was removed by flushing.

Fish were reared on a commercial (e.g., Biodiet) diet. Swimup fry were fed a semimoist starter “crumble”. At about 1 g body weight, the fish were fed a standard pellet semimoist grower ration. At about 100 g body weight, they were converted to a dry diet. Daily ration ranged from 0.4 to 5.6% body weight per day depending on estimated fish size and water temperature (Iwama 1996). The ration was designed to grow the fish on the profile described in Figure 2. Pellet size was determined by feed manufacturer’s recommendations (e.g., Moore-Clark, Biodiet), based on current guidelines for commercial aquaculture and the guidance provided in Fowler (1989). When necessary, pellet size was adjusted from the chart recommendation to ensure the smallest fish in the population were able to feed.

Swimup fry were started with hand feeding in 1.8-m diameter circular tanks. When the fish were greater than 30 g, they were tagged and transferred to 3.7-m diameter circular tanks where their diet was rationed by automated feeders (Allen or belt feeders). Each day, prior to loading the feeders, a small portion of the day’s ration was broadcast over the surface to observe the fish’s feeding response. The feeding frequency varied with day length, feeder type and fish size, as suggested by Fowler (1989).

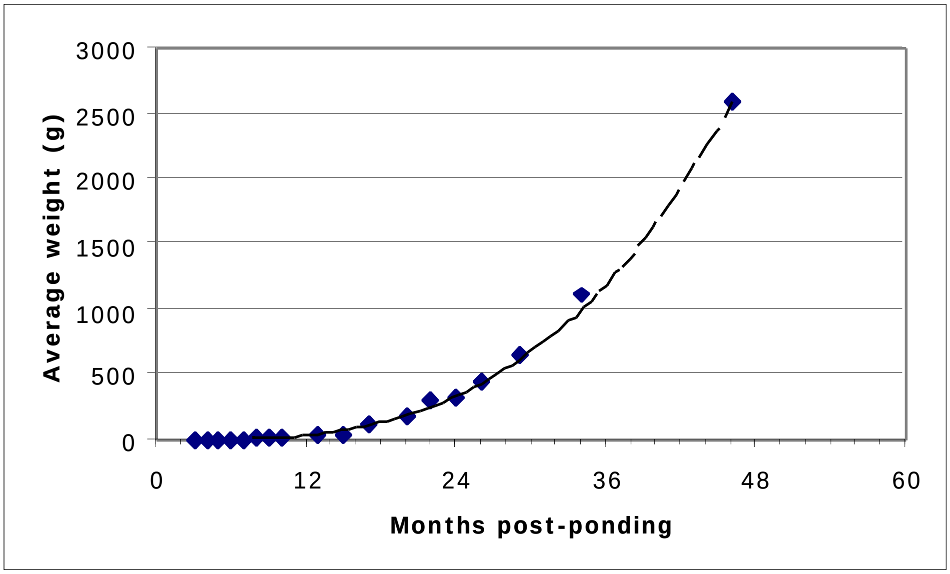

Figure 2. Growth rate projection for Redfish Lake sockeye salmon reared in 10°C freshwater at Burley Creek Hatchery. Growth profile based on historical data for sockeye reared in freshwater by NMFS.

Fish maintained in the captive broodstock program were tagged with passive integrated transponder (PIT) tags as presmolts (Prentice et al. 1990) using a separate, disinfected needle for each fish. The individual tag codes were used to maintain individual fish pedigrees, which were utilized at spawning to determine mating crosses.

In general, the fish were handled with extreme care and kept in water to the maximum extent possible during transport and processing procedures. Whenever possible, fish were transferred with a fish transfer tube that held water to prevent the added stress of a waterless transfer. Center standpipes in rearing tanks were constructed to hold at least 15 cm of water depth in the tank when the external standpipe was pulled to lower tank water level. This minimized the chance of fish being accidentally dewatered during tank draining or flushing.

Transportation of juvenile or adult fish emphasized fish health and safety. All transportation occurred in insulated containers, and temperature was not allowed to rise more than 2°C. The transport containers were supplied with a continuous oxygen supply that maintained dissolved oxygen at full saturation. The oxygen reservoir contained at least twice the oxygen needed to make the entire trip. The containers were loaded at no more than 0.06 kg/L (0.5 lb/gallon).

The fish were maintained on low levels of natural lighting and natural photoperiod. In order to minimize the impact of handling stress, the fish were not routinely sampled in past years. This resulted in only end point data, such as maturation age, size, fecundity, survival, and the primary cause of death being routinely collected. However, in the current reporting period, fish in some tank populations were subsampled occasionally to assess fish weight and length for determining adherence to the growth profile.

Fish health was monitored in several ways. Fish were observed daily for feeding response, external condition, and behavior of fish in each tank as initial indicators of developing problems. In particular, signs of lethargy, spiral swimming, side swimming, flashing, unusual respiratory activity, body surface abnormalities, and unusual coloration were noted. A fish pathologist examined captive broodstock mortalities to determine cause of death. When a treatable pathogen was either detected or suspected, a NMFS veterinarian, in consultation with IDFG fish health staff, prescribed appropriate prophylactic and therapeutic drugs. Medication was mixed with the feed, with dosage based on the fishes' weight. In addition, maturing fish were injected with erythromycin one month prior to spawning. Select mortalities were preserved as appropriate for pathology, genetic, and other analyses. After necropsy, specimens that were not vital to further analysis were disposed of in a manner consistent with ESA permits.

Redfish Lake sockeye salmon in the captive broodstock and adult release programs were reared to adulthood at MRS, BBC (until July 2001) and BCH (beginning July 2001) facilities. During the year of expected maturation feeding was discontinued in late spring to coincide with expected time of Columbia River entry for wild fish. Maturing fish reared in seawater at MRS were transferred to freshwater for final maturation in mid-summer when external signs of maturation became visible. Signs of maturation were determined by changes in skin sheen, skin coloration, body morphology, and, more recently, ultrasound examination of gonadal status. Fish were transferred to freshwater as close as possible to the time that natural migrating sockeye salmon would enter freshwater. In late summer, fish in the adult release program were transported from BCH to Idaho for release.

During the spawning season, typically after October 1, mature captive broodstock salmon were anesthetized with tricaine methanesulfonate (MS-222) and checked for ripeness on a weekly basis. Hormone implants consisting of gonadotropin releasing hormone analog (GnRHa) were injected into the dorsal sinus of some unripe fish to expedite ovulation and spermiation to coordinate spawning timing between males and females (Swanson 1995). Fish that were ready to spawn, as determined by egg or milt expression (FRED 1983), were humanely killed and had their PIT tag, length, and weight recorded. Females were incised through the caudal peduncle to facilitate blood drainage and limit blood accumulation with the eggs that might clog the eggs' micropyles. Females were bled for 3 - 5 minutes, then abdominally incised and the eggs collected into a plastic bag. The eggs from each female were divided into two approximately equally numbered groups and placed in a cooler until fertilization. Males were live-spawned, and milt was collected into Whirl-pak bags by compressing the abdomen. Milt motility was checked visually with a microscope.

All spawned fish were analyzed for common bacterial and viral pathogens, e.g., *Renibacterium salmoninarum*, the causative agent for bacterial kidney disease (BKD), infectious hematopoietic necrosis virus, etc. Tissue samples collected from the kidney, spleen and pyloric caeca of each fish and ovarian fluid samples collected from each female were sent to a NWFSC lab for analysis. Egg transfers were based upon IDFG-established criteria for BKD enzyme-linked immunosorbent assay (ELISA) optical density (OD) levels. The actual numbers fluctuated based upon the type of conjugate used in the ELISA process, however, the criteria was the same and ensured that only offspring from low ELISA females were returned to Idaho. Eggs from females with low OD levels were returned directly to Idaho. Eggs from females with moderate OD levels were sent to BFH for rearing to smoltification. Fish health sampling following the above criteria was used to determine whether the fish could be certified for return to Idaho as smolts. All eggs from females with high ELISA levels were culled.

Mating strategies were structured to maintain genetic diversity. These strategies included pairing in as many different combinations as possible, avoidance of pairing between siblings, fertilization between different year classes and fertilization with cryopreserved sperm from other generations as suggested by Hard et al. (1992).

Eggs were fertilized following "dry method" procedures. Milt from one male was pipetted into a plastic bag containing about half the eggs of one female. The eggs and milt were gently mixed for several seconds, well water was then added to activate the sperm, and the eggs were lightly agitated to distribute the activated milt. The bags were left undisturbed during the initial stages of the fertilization process. After about five minutes, the eggs were water hardened in a 1:100 buffered iodophore solution for 20 minutes and placed in down-flow containers for isolated incubation. Beginning two days after fertilization, the eggs were treated with formalin injected into the water supply at 1,668 ppm for 15 minutes on alternating days for control of *Saprolegnia* spp. The eggs were left undisturbed during the sensitive period beginning 48 hours after fertilization until they reached the eyed stage. Eyed eggs were shocked and weighed. Dead or unfertilized eggs were removed and counted or weighed to determine eyed-egg viability rates.

Eggs to be shipped to Idaho or BFH were placed into open mesh plastic tubes (27-cm long by 6-cm diameter) at approximately 2,700 eggs per tube. Each packed tube was wrapped in wet cheesecloth and placed in a small shipping container. Ice was placed in a top layer of cheesecloth to keep the eggs cool and moist during shipment. Shipment to Boise, Idaho was by a common carrier flight of two hours. Shipment to BFH was 3.5 hours by motor vehicle.

SMOLT RELEASE FISH CULTURE PRACTICES

NMFS coordinated the Mitchell Act funded rearing of fish at BFH through the SBSTOC. The transferred eggs were reared in standard heath trays supplied with pathogen-free well water. Maximum densities of 4,000 eggs/tray were maintained until swimup. Trays were checked on a weekly basis for dead eggs, which were counted and removed. Fish were ponded when they reached the swimup fry stage as indicated by swimming behavior.

Swimup fry were ponded into the Canadian troughs located within the Old Bonneville Hatchery Building for initial rearing. They were reared on well water with a rearing density ranging to a high of 1.6 kg/m^3 (0.75 lbs/ft^3) and loading density not exceeding 6.06 kg/Lpm (1.6 lbs/gpm). The troughs were covered with mesh to prevent fry from jumping out. Food and fecal material falling to the bottom of the trough was removed by vacuuming. When the fish reached approximately 0.7 g, they were moved to 2.7-m diameter circular tanks inside the building. When the fish reached 9 g they were transferred to outside concrete raceways supplied with either well water or Tanner Creek water, where they remained until they were transferred to the Stanley Basin as 50 to 60 g smolts. The raceways were fully covered with 2.5 x 2.5 cm-mesh covers to prevent avian predation and about 80% covered with military specification camouflage net for shade. An electric fence around the raceways reduced the possibility of otter predation.

Incubation, indoor fry rearing, and initial outdoor fry rearing were all done on pathogen-free well water. However, annual well maintenance required the fish in the raceways to be supplied with Tanner Creek surface water for a short time during summer months. The fish were returned to well water when well maintenance was complete.

In general, the fish at Bonneville Fish Hatchery were handled with extreme care and kept in water to the maximum extent possible during transport and all other fish culture or sampling procedures. These procedures corresponded with those described for captive broodstock fish handling and transportation.

The fish at Bonneville Hatchery were reared on a commercial (e.g., BioOregon) grower diet. The daily ration ranged from 1.5 to 5.2% per day depending on estimated fish size and water temperature (Iwama 1996). Pellet size followed the guidelines provided in Fowler (1989). If necessary, pellet size was adjusted to ensure the smallest fish in the population could feed. Swimup fry were initially hand fed in the Canadian troughs, graduating to automatic feeders when they grew larger. In the raceways, automated feeders broadcast food over the surface about two to nine times a day during daylight hours (Fowler 1989). The feeding frequency was varied with both day length and fish size.

All Redfish Lake sockeye salmon reared at Bonneville Fish Hatchery were tagged with coded-wire tags (CWT). A tag retention check was performed about 30 days after tagging. The CWT information will be used by IDFG to identify the origin of returning adult fish in 2002 and 2003 and determine straying and smolt-adult survival rates. In addition to the CWT tagging, a small subsample of 1,000 fish was PIT tagged in March

2001. The PIT tag information was used by IDFG to determine migration timing and survival of juvenile fish through the hydropower system.

Fish health was checked daily by observing feeding response, external condition, and behavior as initial indicators of developing problems. An ODFW fish pathologist routinely monitored mortalities to determine cause of death. When a treatable pathogen was either detected or suspected, appropriate therapeutic drugs were administered. After necropsy, specimens that were not vital to further analysis were disposed of in a manner consistent with the Project's ESA permit.

NMFS coordinated the rearing and release of these smolts and obtained appropriate health certifications and permits for interstate transport of the smolts. NMFS coordinated all its transfers of eyed eggs and fish with the other agencies and tribes involved in Snake River sockeye salmon recovery through the SBSTOC. The release of these captive broodstock groups into the Upper Snake River Basin is expected to help restore a viable run of anadromous sockeye salmon to the area.

SPAWNING AND REARING ACTIVITIES

During the reporting period, NMFS reared the following six Redfish Lake Sockeye Salmon genetic lineages in its captive broodstock program:

1) third generation progeny (brood-year 1998) of the one female and three male sockeye salmon that returned to Redfish Lake in 1991;
2) second generation progeny (brood-year 1996) of the two female and six male sockeye that returned to Redfish Lake in 1993;
3) first (brood-year 1996), second (brood-years 1998 and 1999) and third generation progeny (brood-year 2000) of the one female sockeye salmon that returned to Redfish Lake in 1996;
4) second (brood-year 1997) and third (brood-year 2000) generation progeny of the one female that returned to Redfish Lake in 1994;
5) first generation progeny (brood-year 1999) of the single female and three of the six male sockeye salmon that returned to Redfish Lake in 1999;
6) first generation progeny (brood-year 2000) of females that returned to Stanley Basin lakes in 2000.

Fall 2000

Adult release fish transfer

In September 2000, 61 sockeye from the brood-year 1997 adult release group reared in seawater at MRS matured and were transported to Stanley Basin lakes and released for natural spawning. These fish were not mature enough to determine sex ratios. The fish averaged 43 cm and 0.9 kg in size. Thirty-six fish were released into Redfish Lake, and 25 fish were released into Pettit Lake.

Captive broodstock spawning

In September 2000, the maturing brood-year 1997 sockeye were injected with erythromycin as a prophylactic treatment prior to spawning. In early October, about 60 males were implanted with GnRHa. Females that seemed to be ripening slowly were implanted with GnRHa later in October. A total of 66 females and 49 of the 60 males that matured were spawned. Survival of these brood-year 1997 fish from egg to age three adults was about 71%. Spawning began October 11 and continued through November 1. Females averaged 54.2 cm in length and 2.3 kg in weight. Males averaged 54.1 cm in length and 2.5 kg in weight. Fecundity averaged 2,266 (range 1,859 – 2,616; 985 eggs/kg of female weight). The fertilization rate for the first four weeks of spawning was 73%. The fifth (final) week of spawning lowered the overall fertilization rate to 62.7% (Table 1) due to many of the remaining females being overripe in that final week (Frost et al. 2001). All parents met IDFG BKD ELISA criteria for transfer of eggs to Idaho for use in recovery efforts. Approximately 54,991 eggs were returned to Idaho under ESA Permit 1148, WDFW Transfer Permit 3362-11-00, and IDFG Transfer Permits HQ-00-099 and HQ-00-109. An additional 37,854 eggs were transported to BFH for the smolt release program in November and December 2000 under ESA Permit 1148, WDFW Transfer Permit 3363-11-00 and ODFW Authorization Letter issued 20 November 2000.

In October 2000, two second generation (F2) brood-year 1996 (1993 lineage) and one brood-year 1996 females were spawned and fertilized with milt from brood-year 1997 F2 males. These females averaged 58.2 cm and 2.7 kg. Fecundity for these age-4 females was 1,861 eggs. Unfortunately the fertilization rate was 28%, producing approximately 1,573 eggs. About 250 eyed eggs were combined with the brood-year

1997 sockeye salmon eggs that were sent to IDFG, and about 1,323 eyed eggs were combined with the shipment that went to BFH.

There were no remaining brood-year 1996 or 1997 Redfish Lake sockeye salmon in the captive broodstock program after the 2000 spawning season. Because of the continuously poor results obtained from the few fish that survive to age-4 spawning due to egg atresia, five brood-year 1997 bright fish that did not mature were sacrificed and examined for reproductive condition. One fish was a male and the remaining fish were females with varying degrees of egg atresia that probably would not have been productive as age-4 adults.

Fish Culture

Brood-year 1997

This adult release group was transferred from IDFG's brood-year 1997 production group to MRS in May 1999 as smolts to rear to maturity in seawater. Survival from smolt to age-4 adult has been 64%. In July 2001 these fish (N = 141) were transferred to the BCH freshwater facility for final maturation. In September, the majority of these fish will be transported to Stanley Basin lakes for volitional spawning. Some fish will remain at BCH to provide genetic variability for NMFS fall 2001 spawning in October.

Brood-year 1998

The 1998 captive broodstock is comprised of two distinct half-sibling groups sharing a common father. The first group of fish is the second-generation (F2) progeny from IDFG 1996 captive broodstock from the lone returning female sockeye salmon to Redfish Lake in 1996. The eggs from this broodstock were fertilized with milt from the lone returning wild male in 1998. IDFG transferred 55 eggs to NMFS in 1998. The second group contains third-generation (F3) progeny (descendents of the IDFG 1991-brood wild fish) from the 1998 spawning of NMFS 1994 brood-year sockeye that had been reared to smoltification at BFH and then transferred to MRS for rearing to maturation. These eggs were also fertilized with milt from the lone returning male sockeye salmon to Redfish Lake in 1998. NMFS retained 400 eggs, 254 of which survived to hatch. NMFS transferred 127 of the surviving eggs to IDFG and retained 127 for captive broodstock. After PIT tagging in 1999, these two half-sibling groups were combined. Survival for the 1996 lineage fish to August 31 has been 47%. Survival for the 1994 lineage fish has been 64%. The majority of these fish are expected to spawn in 2001, with the remainder spawning in 2002.

The second brood-year 1998 group is comprised of fish from the 1996 brood-year half-sibling group that was dedicated to the adult release program. These fish were reared to maturity at MRS and transported to BCH for final maturation in August 2001. Survival from smolt to adult through August 2001 has been 71 %. During their seawater rearing these fish incurred outbreaks of BKD and *Flexibacter maritimus*. Because of these health issues these fish will remain with NMFS and will be spawned at BCH in fall 2001.

Brood-year 1999

NMFS is currently maintaining a captive broodstock and an adult release group of this brood-year at BCH. The captive broodstock group is comprised of second generation fish from the IDFG 1996 brood-year captive broodstock and first generation fish from the lone returning female sockeye salmon to Redfish Lake in 1999. NMFS currently has 368 of these fish in its custody. These fish were PIT tagged in September 2000 and combined into 4.1-m rearing tanks in November. Survival in this group has been 62% through August 2001. These fish are expected to mature and spawn between 2002 and 2003.

The adult release group contains first generation offspring from the lone-returning female sockeye salmon in 1999 and second generation offspring from the IDFG brood-year 1996 captive broodstock. Survival through August 2001 has been 48%. In November 2000, a total of 147 fish were lost after transfer to a larger tank. The loss may have been due to inadequate flushing of the tank after iodophore disinfection. NMFS currently has 192 of these fish in its custody. The remaining fish are expected to mature and spawn between 2002 and 2003.

In fall 1999, NMFS transferred 17,761 eggs from parents with ELISA OD levels between 0.2 and 0.4 to BFH for rearing in the smolt release program. Approximately

16,000 alevins were ponded in February 2000. These fish were given prophylactic Aquamycin antibiotic treatments in June and September 2000. All fish were coded-wire tagged and adipose-fin clipped in October 2000. In addition, 1,000 fish were PIT tagged in March 2001. Fish health samples conducted on these fish in October 2000 and April 2001 were negative for the presence of BKD. These fish had a survival of 87% from ponding through April 2001. Approximately 13,915 smolts were transported to Upper Salmon River Basin and released in May 2001.

Brood-year 2000

In fall 2000, NMFS received 347 eggs from IDFG for the captive broodstock program. These fish are the result of matings between males and females from several different lineages: anadromous-returning sockeye salmon (1993- and 1996-broods) and captive-reared sockeye salmon (1997- and 1998-broods) from IDFG Eagle Hatchery. In addition IDFG transported an additional 42 fry in February 2001. Egg to ponding survival was 98%. NMFS currently has 362 of these fish in its custody. Survival in the individual groups ranges from 85 to 100%, with an overall survival of 93%.

NMFS retained 538 eggs from the 1997 F2 females (1994-brood) reared at BBC for the adult release program. Egg to ponding survival was 83%. The current overall survival is 75%, with 402 fish remaining. Approximately 200 fish will be transferred to seawater at MRS in May 2002. These fish are expected to mature in fall 2003 and 2004 and be released into Stanley Basin lakes for volitional spawning.

In fall 2000, NMFS transported 37,900 eggs from healthy brood-year 1997 F2 parents (ELISA OD < 0.2) to BFH for the smolt release program. These eggs were combined with about 1,300 eggs from brood-year 1996 F2 females from NMFS, plus 70,149 eggs from IDFG's captive rearing program for a total of 109,300 eggs for the smolt release program. ODFW ponded 96,096 alevins in February 2001. In May they were given their first treatment of Aquamycin. Mortalities of unknown etiology occurred throughout the spring. As of August 31, 2001 the survival rate from eyed egg was 75%. These fish will be coded-wire tagged in fall 2001 and PIT tagged in 2002 for release in May 2002.

SUMMARY

The program has successfully maintained this ESA-listed population in captivity and provided fish for use in restoration. The captive broodstock program provides both freshwater and seawater rearing facilities that help ensure the retention of anadromous traits. Fish were successfully transferred to the new BCH freshwater rearing facility. This program, united with the IDFG captive broodstocks, should continue to provide for the restoration of self-sustaining natural runs of anadromous sockeye salmon to Stanley Basin lakes.

ACKNOWLEDGMENTS

We wish to extend our appreciation to all our partners in IDFG, the Shoshone Bannock Tribe, ODFW, and the University of Idaho for the assistance they provide in making the Redfish Lake Sockeye Salmon Captive Broodstock Program work. We would like to thank Michael Wastel, Bryon Kluver, Kelly Henderson, Dr. William Fairgrieve, and Gail McDowell for their assistance in rearing and/or spawning fish. We greatly appreciate the fish health support provided by Dr. Lee Harrell, Dr. Mark Strom, Cindy Rathbone and Mark Peterson. In addition, Michael Wastel and Bryon Kluver were invaluable in remodeling the Burley Creek Hatchery for the Redfish Lake sockeye salmon program. The funding provided by the Bonneville Power Administration and NMFS Mitchell Act Program was vital to making this captive broodstock program happen.

REFERENCES

Flagg, T. A. and W. C. McAuley. 1995. NMFS Northwest Fisheries Science Center report to NMFS Office of Protected Resources for captive broodstock rearing of Redfish Lake sockeye salmon from December 1991 through December 1994 under ESA Section 10 Propagation Permit 795, 22 p.

Flagg, T. A. and W. C. McAuley. 1996. NMFS Northwest Fisheries Science Center report to NMFS Office of Protected Resources for captive broodstock rearing of Redfish Lake sockeye salmon from December 1994 through December 1995 under ESA Section 10 Propagation Permit 795, 17 p.

Flagg, T. A., F. W. Waknitz, and C. V. W. Mahnken. 1995. The captive broodstock concept: application to Pacific salmon, p. 1-1 to 1-60. *In* T. A. Flagg and C. V. W. Mahnken (editors), An assessment of captive broodstock technology for Pacific salmon. Report to Bonneville Power Administration, Contract DE-AI79-93BP55064.

Fowler, L. G. Feeds and feeding practices for improved fish health. Abernathy Salmon Culture Technology Center, Tech. Transfer Series 88-1.

FRED. 1983. Fish culture manual. Alaska Department of Fish and Game, Juneau, 90 p.

Frost, D. A., W. C. McAuley, D. J. Maynard, and T. A. Flagg. 2001. NMFS Northwest Fisheries Science Center report to NMFS Office of Protected Resources for captive broodstock rearing of Redfish Lake sockeye salmon from January through December 2000 under ESA Section 10 Propagation Permit 1148, 18 p.

Hard, J. J., R. P. Jones, Jr., M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS NWFSC-2, 56 p.

Iwama, G. K. 1996. Growth of salmonids. *In* W. Pennell and B. A. Barton (editors), Principles of salmonid culture, p. 467-516. Elsevier, Amsterdam.

Kline, P. K. and C. Willard. 2001. Snake River sockeye salmon Captive Broodstock Program, Hatchery Element. Annual Progress Report, January 1 - December 31, 2000. Report to Bonneville Power Administration. Project No. 199107200, Contract No. 00000167, 36 p.

Leitritz, E. and R. C. Lewis. 1976. Trout and salmon culture (hatchery methods). Calif. Dep. Fish Game, Fish Bull. 164, 197 p.

McDaniel, T. R., K. M. Pratt, T. R. Meyers, T. D. Ellison, J. E. Follet, and J. A. Burke. 1994. Alaska sockeye salmon culture manual. Alaska Department of Fish and Game, Special Fisheries Report Number 6, 39 p.

Novotny, A. J., J. L. Mighell, and T. A. Flagg. 1985. Low-flow isolation system for salmonid egg incubation, p. 8-13. Proceedings of the 35th Annual Fish Culture Conference, 1984, Kennewick, WA.

Pennell, W. and B. A. Barton (editors). 1996. Principles of salmonid culture. Elsevier, Amsterdam, 1039 p.

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard. 1982. Fish hatchery management, U.S. Dep. Inter., U. S. Printing Office, Washington, DC, 517 p.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D. C. Cross. 1990. Equipment, methods, and automated data entry station for PIT tagging. Amer. Fish. Soc. Symp. 7:335-340.

Schiewe, M. H., T. A. Flagg, and B. A. Berejikian. 1997. The use of captive broodstocks for gene conservation of salmon in the western United States. Bull. Natl. Res. Inst. Aquacult. Suppl. 3:29-34.

Schreck, C. B., M. S. Fitzpatrick, and K. P. Currens. 1995. Pacific salmon. *In* N. R. Bromage and R. J. Roberts (editors), Broodstock management and egg and larval quality, p. 197-219. Blackwell Science, Oxford.

Swanson, P. 1995. Environmental and endocrine control of reproduction in cultured salmonids, p. 3-1 to 3-66. *In* T. A. Flagg and C. V. W. Mahnken (editors), An assessment of captive broodstock technology for Pacific salmon. Report to Bonneville Power Administration, Contract DE-AI79-93BP55064.

TABLES

Table 1. Weekly fecundity and egg viability for 1997 brood Redfish Lake sockeye salmon reared to age-3 and spawned at NMFS facilities, 2000.

Week/Date of spawning	Females spawned	Fecundity (eggs/fish)	Green eggs (n)	Eyed eggs (n)	Viability (% to eye)
Week 1 / Oct. 11	8	2,271	18,166	13,371	73.6
Week 2 / Oct. 18	18	2,223	40,006	32,299	80.7
Week 3 / Oct. 24	17	2,100	35,699	25,146	70.4
Week 3 / Oct. 26	7	2,528	17,694	11,911	67.3
Week 4 / Nov. 1	6	1,859	11,156	6,387	57.3
Week 5 / Nov. 9	11	2,616	26,162	4,269	16.3
Total	67	2,266	148,885	93,383	62.7